UiO : University of Oslo

TIK **Centre for technology, innovation and culture**
P.O. BOX 1108 Blindern
N-0317 OSLO
Norway

Eilert Sundts House, 7th floor
Moltke Moesvei 31

Phone: +47 22 84 16 00
Fax: +47 22 84 16 01

http://www.sv.uio.no/tik/
info@tik.uio.no

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Cooperation and innovative performance of firms: Panel data evidence from the Czech Republic, Norway and the United Kingdom [*]

GlobInn, EU 7th FP project

Martin Srholec
Centre for Technology, Innovation and Culture (TIK)
University of Oslo
(e-mail: martin.srholec@tik.uio.no)

Abstract

Using panel micro data obtained from merging several waves of Community Innovation Survey in the Czech Republic, Norway and the United Kingdom, we estimate dynamic random effects tobit models, in which the innovation output given by sales of innovative products is the function of the cooperative behaviour of firms and their other observed characteristics, while accounting for unobserved heterogeneity. The results indicate that the capacity of firms to build on external domestic linkages is what matters most for the innovation output. And that foreign external linkages lead to superior innovation performance only in combination with the domestic ones. Also the results suggest that the positive effect of domestic cooperation is driven by linkages to education, research and scientific institutions, even though these types of partners tend to be used by firms noticeably less frequently for cooperation on innovation than their suppliers and customers.

Keywords: Innovation; cooperation; performance; micro data; Community Innovation Survey.

[*] Sources of the micro data are the Czech Statistical Office, Statistics Norway and the Office of National Statists (ONS) in the United Kingdom. The statistical data from ONS which is Crown copyright and reproduced with the permission of the controller of HMSO and Queen's Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates. I am grateful to them for providing access to the micro data. Financial support from the EU 7th FP project on "The changing nature of Internationalization of Innovation in Europe: impact on firms and the implications for innovation policy in the EU" (GlobInn), SSH-CT-2008-217296 is gratefully acknowledged. I thank participants at GlobInn workshops, in particular Suma Athreye, René Belderbos, Pari Patel and Reinhilde Veugelers, for helpful comments and suggestions. All usual caveats apply.

1. Introduction

Traditionally, because of data availability, dynamic panel data analyses of innovation focused on the relationship between R&D and patents in the framework of knowledge production function on one hand and the effects of R&D and/or patents on performance of firms on the other hand (Mairrese and Mohnen 2010). But R&D (and innovation) may be conducted in many ways and with different productivity in terms of firm's performance. For example, innovation projects could be conducted jointly with other organizations. Does this make a difference for the returns of firms on their innovation activity? Are cooperative projects more productive in generating new products and sales thereof? And what kind of partners is the most productive in this respect?

Over the last two decades the Community Innovation Survey (CIS) has been conducted regularly in many countries offering new evidence of the innovative behaviour of firms. But so far the vast majority of empirical research on cooperation in the innovation process has relied on cross-sectional evidence (Srholec 2010), which leaves us in the dark with regards to the dynamic aspects of innovation. Since these surveys are conducted quad-annually and bi-annually in the recent years, and the early (pilot) surveys are not fully compatible with the recent evidence, only now relevant panel datasets become to emerge that allow researchers to study longitudinal evidence based on these surveys in an econometric framework.

To the best of our knowledge, however, only Raymond, et al. (2009) provides dynamic evidence on the link between innovation inputs, outputs and the performance of firms that takes into account the cooperative behaviour of firms. Yet they used only the overall cooperation variable, without considering the heterogeneity of partners by location or type, and included this variable in the current period, not examining the lagged effects of cooperation in the panel estimate. Although they did not even report the effects of this variable, which hence did not merit much of their attention, they comment in the paper on the fact that those firms that cooperate incur larger R&D or total innovation expenditures and that there are similarly significant results for the innovation output.

The aim of this paper is to contribute to this debate by examining the dynamic relationship between cooperative behaviour of firms and productivity of the innovation process given by sales of innovative products. Using an unbalanced panel of micro data from several waves of CIS in the Czech Republic, Norway and the United Kingdom, we estimate dynamic random effects tobit models, in which the innovation output of firms is the function of cooperation variables and other observed characteristics of firms, while accounting for unobserved heterogeneity. Section 2 presents the panel data. Section 3 outlines the model and debates the econometric strategy. Section 4 gives results of the econometric estimates. Section 5 concludes the paper with policy implications.

2. Overview of the dataset

The empirical analysis is based on panel data at the firm level obtained from merging several waves of CIS conducted by national statistical offices in the Czech Republic, Norway and the United Kingdom, namely the Czech Statistical Office (CZSO), Statistics Norway (SSB) and the Office of National Statists (ONS). Following the Oslo Manual (OECD 1997 and 2005) a harmonized methodology has been used to collect the data. Yet there are several differences in how the respective countries implement the survey and changes of the methodology over time that need to kept in mind when handling the data.

CIS by default collects data only for firms with 10 and more employees. But the data are collected on the base of a sample survey in the United Kingdom, while a combination of a sample survey of small firms (from 10 to 249 employees) and a census of large firms (with at least 250 employees) is used in the Czech Republic and Norway. A random sampling stratified by industry, size categories and more recently by NUTS3 regions is used in the sample surveys. Answering the questionnaire is compulsory in the Czech Republic and Norway, but voluntary in the United Kingdom. Hence, the response rate edged up to 95% in Norway, oscillated between 60 to 80% in the Czech Republic, and increased from around 40 to 60% in the United Kingdom. Obviously, this has consequences for the potential for creating a panel dataset.

Table 1 provides overview of the data. To create a panel dataset we merged four consecutive waves of CIS in each country. CISw1, CISw2, CISw3 and CISw4 shortcuts indicate the respective wave of the survey.[1] CIS has a three-year reference period.[2] Even though there is one-year overlap between some of the consecutive periods, this does not pose a problem in this paper, because as further explained below the dependent variable refers to outcomes in the final year of the period, i.e. the reference periods of lagged predictors and the dependent variable do not overlap with each other.

[1] Earlier surveys conducted in Norway and the United Kingdom, i.e. the so-called CIS1, provide data not sufficiently compatible with the subsequent evidence to be included in the panel. Unfortunately, data from the latest CIS2006-2008 in Norway and the United Kingdom had not been disseminated for research purposes before this analysis has been conducted. CIS1 and CIS2, i.e. with reference periods in the nineties, were not conducted in the Czech Republic.

[2] CISw2 in the Czech Republic is the only exception with two-year reference period over 2002-2003, but this should not lead to a serious bias here, because the dependent variable refers to innovative sales in the final year.

Table 1: Overview of the CIS data

Wave	Reference period			Number of observations		
	Czech Republic	Norway	United Kingdom	Czech Republic	Norway	United Kingdom
CISw1	1999-2001*	1995-1997*	1994-1996	2,841	2,933	2,109
CISw2	2002-2003*	1999-2001*	1998-2000	3,495	3,438	6,184
CISw3	2004-2006*	2002-2004*	2002-2004	6,235	3,732	4,906
CISw4	2006-2008*	2004-2006	2004-2006	6,583	5,120	4,876

Note: * The questionnaire was filtered for INNACT=0 firms.

CIS in the earlier periods focused primarily on gathering data on industrial enterprises (10-41), whereas the coverage of firms operating in market services (50-74) has improved only gradually over time. Some sectors have been covered erratically and therefore for the sake of harmonization excluded from the sample, namely the sectors of construction (45), repair, wholesale and retail trade (50-52) and hotels and restaurants (55). NACE, rev. 1.1 codes are denoted in the brackets. Because of the combined effect of extending the sectoral coverage and the general trend of improving response rates, the number of observations available for creating the panel dataset tends to increase over time.

Nevertheless, as a consequence of the random stratified sampling, i.e. of the fact that a somewhat different pool of respondents is drawn from the targeted population in each wave of the survey, a certain proportion of the firms appears in the data only once, and therefore cannot be used in the dynamic analysis. Table 2 reveals the longitudinal distribution of the data.[3] From this follows that an unbalanced panel, which includes firms that are present in at least two consecutive surveys, covers about 29%, 34% and 46% of the firms in the Czech Republic, Norway and the United Kingdom, respectively. Note that in the latter country the last survey has been deliberately designed to collect data for the same firms that answered the preceding one, so most of the unbalanced panel comes from the last two periods. [4]

[3] In the first column of the table, this is depicted by a string of "0" for being missing and "1" for being present in the respective period; hence, for example, "1111" denotes that the firm appears in all four waves of the survey, whereas "0011" means that there is data for the given firm in the last two periods, and "0001" means that the firm is observed only at one point in time.

[4] For confidentiality reasons, 36 firms in the United Kingdom must be reported together in the "undisclosed" category.

Table 2: Longitudinal pattern of the data

Pattern	Czech Republic		Norway		United Kingdom	
	Firms	%	Firms	%	Firms	%
1111	644	5.11	639	6.88	47	0.39
0111	596	4.72	649	6.99	322	2.66
0011	1,497	11.87	823	8.86	4421	36.54
1011	182	1.44	117	1.26	53	0.44
1110	105	0.83	195	2.10	n.a.	n.a.
0110	241	1.91	304	3.27	n.a.	n.a.
1101	97	0.77	61	0.66	n.a.	n.a.
1100	292	2.31	387	4.17	661	5.46
0101	256	2.03	200	2.15	n.a.	n.a.
1001	196	1.55	117	1.26	n.a.	n.a.
1010	165	1.31	144	1.55	n.a.	n.a.
1000	1,160	9.20	1,273	13.71	1347	11.13
0100	1,264	10.02	1,003	10.80	5151	42.58
0010	2,805	22.24	861	9.27	60	0.50
0001	3,115	24.69	2,514	27.07	n.a.	n.a.
Undisclosed	0	0	0	0	36	0.30
Total	12,615	100.00	9,287	100.00	12,098	100.00

Table 3 provides definitions of the variables. TURNINN is the measure of innovation output, which refers to the proportion of products that were innovated over the reference period in total turnover in the final year of the reference period. At the centre of our interest are the CO variables for cooperation, which are derived from the set of questions on whether the firm cooperated on innovation with other organizations over the reference period. Firms were asked to report the location and type of the partner. As far as the location is concerned, firms reported whether the partner was domestic or foreign, from which we derive the "dom" and "for" abbreviations. Several types of the partner organisation have been distinguished, including other firms within the respondent's group, suppliers, customers, competitors, commercial labs, universities and public research institutes. From this follows the basic distinction between internal cooperation with other members of the group denoted by "GP" and external cooperation with the other types of organizations not affiliated to the group given by "EXT".

Table 3: Definition of the variables

TURNINN	Sales of innovated products as the proportion of total turnover
COforEXT	Dummy variable with value 1 if the firm has a cooperation arrangement on innovation with a foreign non-affiliated partner
COdomEXT	Dummy variable with value 1 if the firm has a cooperation arrangement on innovation with a domestic non-affiliated partner
COforGP	Dummy variable with value 1 if the firm is affiliated to a group and cooperates on innovation with a foreign member of the group
COdomGP	Dummy variable with value 1 if the firm is affiliated to a group and cooperates on innovation with a domestic member of the group
GPnonCO	Dummy variable with value 1 if the firm is affiliated to a group but does not cooperate on innovation with the group members
R&DIN	Intramural R&D expenditure as % of turnover
R&DEX	Extramural R&D expenditure as % of turnover
MAC	Acquisition of machinery and equipment specifically purchased for the purpose of innovation as % of turnover
ROEK	Acquisition of other external knowledge specifically purchased for the purpose of innovation as % of turnover
PAT	Dummy variable with value 1 if the firm applies for a patent
EXPORT	Dummy variable with value 1 if the firm exports
SIZE	Log of employment
HT	Dummy variable with value 1 if the principal activity of the firm is classified in a high-tech (HT) manufacturing sector according to OECD (2003, pg. 156)
MHT	Dummy variable with value 1 if the principal activity of the firm is classified in a medium-high-tech (MHT) manufacturing sector according to OECD (2003, pg. 156)
MLT	Dummy variable with value 1 if the principal activity of the firm is classified in a medium-low-tech (MLT) manufacturing sector according to OECD (2003, pg. 156)
LT	Dummy variable with value 1 if the principal activity of the firm is classified in a low-tech (LT) manufacturing sector according to OECD (2003, pg. 156)
KIS	Dummy variable with value 1 if the principal activity of the firm is classified in a sector of knowledge-intensive services (KIS) according to OECD (2003, pg. 140)
OTH	Dummy variable with value 1 if the principal activity of the firm is classified in other (OTH) residual sector not covered by OECD (2003, pg. 140 and 156)

Hence, there are four dummy variables COforEXT, COdomEXT, COforGP and COdomGP for the respective location and type of partners. In addition, because so many cooperating firms engage simultaneously with foreign and domestic partners, we create from these variables three mutually exclusive categories of firms that either cooperated only with partners abroad, only with partners at home or with both of them; these are delineated in the following econometric analysis by two more sets of shortcuts CObothEXT, COforEXTonly, COdomEXTonly for the external partners and CObothGP, COforGPonly, COdomGPonly for

the within group cooperation. Finally, GPnonCO denotes the residual category of firms that are affiliated to a group but do not cooperate on innovation with the other members. [5]

In addition, there is a battery of variables that account for resources, capabilities and structural features of the firms. R&DIN, R&DEX, MAC and ROEK stand for the intensity of the innovation process on different inputs given by the amount of expenditure on the respective innovation activity as the percentage of turnover in the final year of the reference period. To curtail the influence of outliers, we exclude from the sample firms that reported more than 25% intensity on any of these variables.[6] PAT represents the appropriability conditions of the firms' knowledge base given by the fact whether the firm applied for a patent over the reference period. SIZE and EXPORT account for the structural features, namely the size of the firm represented by log of employment in the final year and the exposure to foreign markets given by the fact whether the firm exports. [7]

Finally, we control for broad sectoral differences by dummy variables derived from the classification of firms in six groups of sectors following the OECD taxonomy of industries based on technology. In the manufacturing sector this taxonomy distinguishes between the so-called high-tech, medium-high-tech, medium-low-tech and low-tech industries (Hatzichronoglou 1997, OECD 2003, pp. 140 and 156), denoted by the HT, MHT, MLT and LT shortcuts. Only relatively recently this taxonomy has been extended to the service sector by including the category of so-called knowledge-intensive services, which is denoted by the KIS dummy, and which covers the sectors of post and telecommunications (64), finance and insurance (65-67) and the other business activities excluding real estate and renting (72-74); NACE, rev. 1.1 codes are in the brackets. OTH refers to the mixed bag of other residual sectors not covered above, such as mining and quarrying, electricity, gas and water supply and transport.

Yet there is one more difference in how the data is collected that needs to be explained. Oslo Manual (OECD 1997 and 2005) defines the category of "innovation active" firms as those that responded positively at least to one of the questions asking them whether they introduced a new product, a new process and whether they had not yet completed (ongoing) or abandoned innovation activities. Accordingly, the harmonized CIS questionnaire devised by Eurostat uses this distinction to filter the way how the respondents are expected to fill in the survey, so only the "innovation active" firms are asked to report details on their innovation activity regarding the types of innovation expenditure, cooperation on innovation, etc. In other words, firms that do not report to innovate, not even claim to have ongoing or abandoned efforts, do not answer the more detailed questions.

[5] Unfortunately, the GPnonCO variable lumps together firms affiliated to a group with headquarters in the same country and abroad, because the location of headquarters is not possible to distinguish in the early surveys conducted in Norway and the United Kingdom.

[6] In fact, these extreme values were in many cases mere measurement errors caused by the fact that the firm mistakenly answered the question on turnover in thousands of the local currency units, but the questions on innovation expenditures in the full amount, generating exceptionally high ratios between them. Also these indicators are defined in terms of turnover, so the intensity in terms of value added is much higher, and therefore generally not feasible beyond this threshold, except perhaps of special circumstances, which are not the concern of this paper.

[7] It should be noted that definition of the EXPORT dummy has changed over time from the question on whether "the firm's most significant market is international with a distance of more than 50 km" used in (CIS3 and the earlier) surveys with reference periods ending before 2002 to the question whether "the firm sells goods or services to foreign markets" used in the more recent (CIS4 and later) surveys.

But not every statistical office follows the suit. Table 1 indicates with the asterisk, which of the surveys in fact adopted this recommendation. None of the questionnaires used in the United Kingdom did resort to the filtering. And in Norway this is the case of the last version of the questionnaire. As a result, in about half of the surveys we have non-filtered data, but in the other half there is missing information on the more detailed questions for those firms that have been spared from answering them. How should we harmonize this? Since the firms that declared not having any innovation activity whatsoever, logically could not have reported a positive number on these missing figures, we impute zeros to these firms in the variables affected by the filtering. Alternatively, we could refrain from inferring the zeros and focus on the (persistently) innovation active firms only. But this would lead to a potential sample selection bias, which is quite computationally burdensome to handle in the panel data framework.

Table 4 compares averages of the variables in the total pooled dataset and the unbalanced panel that is available for the econometric estimates. After omitting observations with incomplete records and with the excessive (more than 25%) intensity on the innovation expenditure variables, we arrive to an unbalanced panel of 3,079 firms with 8,218 observations in the Czech Republic, 2,905 firms with 7,986 observations in Norway and 5,013 firms with 10,550 observations in the United Kingdom. Hence, the individual firms on average appear in the sample 2.67, 2.75 and 2.10 times in the respective countries out of the maximum of four periods. To a large extent the unbalanced sample accords with the overall dataset in the United Kingdom, while there is a certain bias in the Czech Republic and Norway. Because the data for large firms are collected by census in these countries, which naturally boosts their chances to appear in the sample repeatedly, there is a bias in the size of firms. And this is reflected in differences in the other variables, because large firms are known to have higher propensity to be innovation active, and therefore to cooperate on innovation, etc. [8] Nevertheless, the sectoral composition appears very similar, so there is not a bias along these lines.

[8] Also this explains why the unbalanced panel consists of noticeably more cooperative firms in the Czech Republic and Norway than in the United Kingdom, even though there is a relatively small difference in the overall sample.

Table 4: Averages of the variable in the total sample and the unbalanced panel

	Czech Republic		Norway		United Kingdom	
	Total	Unbalanced panel	Total	Unbalanced panel	Total	Unbalanced panel
TURNINN	0.085	0.109	0.080	0.089	0.101	0.107
COforEXT	0.092	0.144	0.111	0.146	0.075	0.080
COdomEXT	0.144	0.218	0.179	0.225	0.135	0.152
COforGP	0.046	0.076	0.054	0.074	0.045	0.048
COdomGP	0.036	0.058	0.061	0.076	0.055	0.067
GPnonCO	0.253	0.328	0.465	0.510	0.434	0.369
R&DIN	0.004	0.013	0.011	0.026	0.005	0.006
R&DEX	0.001	0.002	0.002	0.005	0.001	0.001
MAC	0.007	0.017	0.004	0.007	0.011	0.014
ROEK	0.001	0.001	0.001	0.019	0.001	0.001
PAT	0.035	0.059	0.081	0.114	0.172	0.229
EXPORT	0.382	0.467	0.498	0.562	0.442	0.464
SIZE	4.328	5.078	3.820	4.183	4.169	4.288
HT	0.051	0.057	0.036	0.046	0.061	0.056
MHT	0.167	0.202	0.111	0.124	0.127	0.123
MLT	0.145	0.133	0.174	0.177	0.134	0.136
LT	0.222	0.194	0.289	0.271	0.209	0.200
KIS	0.240	0.226	0.191	0.186	0.292	0.313
OTH	0.175	0.188	0.209	0.197	0.177	0.172
Num. of obs.	16,013	8,218	9,357	7,986	16,131	10,550
Num. of firms	10,713	3,079	6,437	2,905	11,314	5,013

Note: Number of observations available in the total sample differs by variable due to item non-response.

Table 5 presents more detailed descriptive overview of the variables in the form as they appear in the econometric estimates, i.e. the dependent variable TURNINN is reported in the current period and the predictors are lagged by one period, including the lagged dependent variable. Sectoral classification of the firms is fixed over time, and therefore not reported in the table. For the purpose of this study the most important insight here is the dynamics of these variables. Between standard deviation refers to the variation "between" firms in a given period, while within standard deviation is the variation "within" the same firm over time. Most of the variables show noticeably higher variation between firms than within them over time; suggesting that there is a great deal of persistence.[9] Now the question is whether there are statistically significant relationships between these patterns. More specifically, our aim is to find out whether firms that cooperated on innovation tend to be more productive in terms of innovative sales in the next period.

[9] Since the scope for variation over time increases with the number of periods, the within variation appears particularly low in the United Kingdom, because for the majority of firms in this panel there is data only from the last two surveys. Note that the overall standard deviation of dummy variables is determined by the mean, though for completeness' sake we report both of these statistics.

Table 5: Descriptive statistics of the unbalanced panel data

	Czech Republic				Norway				United Kingdom			
	Mean	Overall st. dev.	Between st. dev.	Within st. dev.	Mean	Overall st. dev.	Between st. dev.	Within st. dev.	Mean	Overall st. dev.	Between st. dev.	Within st. dev.
TURNINN	0.111	0.214	0.197	0.104	0.079	0.173	0.159	0.085	0.088	0.204	0.199	0.043
$TURNINN_{t-1}$	0.107	0.208	0.195	0.102	0.095	0.197	0.182	0.098	0.126	0.247	0.246	0.045
$COforEXT_{t-1}$	0.170	0.375	0.314	0.198	0.151	0.358	0.320	0.145	0.082	0.275	0.267	0.064
$CObomEXT_{t-1}$	0.250	0.433	0.376	0.213	0.223	0.417	0.368	0.212	0.161	0.367	0.359	0.088
o/w $CObothEXT_{t-1}$	0.122	0.327	0.272	0.187	0.138	0.345	0.294	0.187	0.072	0.258	0.251	0.061
$COforEXTonly_{t-1}$	0.017	0.130	0.109	0.080	0.019	0.138	0.113	0.087	0.010	0.101	0.096	0.031
$CObomEXTonly_{t-1}$	0.092	0.289	0.250	0.162	0.090	0.286	0.244	0.172	0.089	0.284	0.279	0.073
$COforGP_{t-1}$	0.090	0.286	0.238	0.146	0.076	0.265	0.228	0.109	0.048	0.214	0.204	0.054
$CObomGP_{t-1}$	0.070	0.255	0.207	0.133	0.072	0.259	0.218	0.146	0.069	0.253	0.247	0.061
o/w $CObothGP_{t-1}$	0.014	0.118	0.096	0.074	0.023	0.151	0.123	0.088	0.019	0.137	0.130	0.040
$COforGPonly_{t-1}$	0.056	0.230	0.194	0.124	0.058	0.234	0.185	0.133	0.029	0.168	0.160	0.044
$CObomGPonly_{t-1}$	0.040	0.195	0.162	0.108	0.053	0.224	0.189	0.133	0.049	0.217	0.213	0.051
$GPnonCO_{t-1}$	0.324	0.468	0.430	0.212	0.518	0.500	0.461	0.240	0.340	0.474	0.461	0.111
$R\&DIN_{t-1}$	0.006	0.021	0.022	0.008	0.014	0.036	0.036	0.013	0.006	0.021	0.021	0.004
$R\&DEX_{t-1}$	0.001	0.007	0.006	0.004	0.003	0.013	0.011	0.007	0.001	0.007	0.007	0.001
MAC_{t-1}	0.008	0.025	0.024	0.013	0.005	0.020	0.018	0.011	0.013	0.032	0.031	0.007
$ROEK_{t-1}$	0.001	0.007	0.006	0.004	0.001	0.009	0.009	0.004	0.001	0.007	0.006	0.002
PAT_{t-1}	0.064	0.245	0.196	0.127	0.116	0.320	0.280	0.152	0.215	0.411	0.405	0.089
$EXPORT_{t-1}$	0.529	0.499	0.479	0.184	0.580	0.494	0.469	0.203	0.449	0.497	0.494	0.073
$SIZE_{t-1}$	5.160	1.397	1.383	0.155	4.252	1.204	1.190	0.204	4.290	1.517	1.490	0.085
Number of obs.	4,750				4,666				5,328			
Number of firms	3,079				2,905				5,013			

3. Econometric model

The aim is to investigate the effect of past cooperative behaviour in the innovation process on the current innovation output. For this purpose the econometric model predicts the innovation output of firms as follows:

$$TURNINN_{it} = \alpha TURNINN_{it-1} + \beta CO_{it-1} + \gamma x_i + \delta_i + \varepsilon_{it}$$

where i is a firm and t is time, so the current innovation output ($TURNINN_{it}$) is the function of the past innovation output ($TURNINN_{it-1}$), past cooperation on innovation (CO_{it-1}), other observable characteristics of the firm (x_i), unobserved individual effects (δ_i) and other time-variant unobserved variables (ε_{it}). Since the model is estimated exclusively at the micro level, for the sake of brevity we do not use i to indicate the firm in the following. Because the dependent variable is truncated between 0 and 1, we use the maximum likelihood procedure to estimate tobit model, and because the number of periods in the sample is rather limited (and therefore some of the key predictors are time-invariant for many firms), we estimate random effects model.

A positive and statistically significant estimate of α indicates the persistence of innovation output. But the focal interest of this study is in the estimate of β, which indicates the effect of lagged cooperation on the innovation output. Besides these predictors, however, there are other characteristics which boost the innovative performance of firms. If these other observables are persistent over time, they induce persistence in the innovation output. Hence, it is essential to control for as many as possible of them. If in addition these characteristics are unobserved, such as the entrepreneurial spirit, latent capabilities or risk profiles of firms, and therefore not controlled for in the estimates, the variables of interest may seem to determine current innovation output because of picking up the effect of these persistent unobserved attributes. Hence, it is important to account for these effects in the estimates with the help of dynamic panel data analysis.

It should be noted, however, that we do not tackle the potential problem of initial conditions described by Heckman (1981) that besets estimating dynamic non-linear models. Wooldridge (2005) proposed and Peters (2009) and Raymond, et al. (2009, 2010) implemented in the context of research on innovation what they call the "simple solution" of this problem. Peters (2009) and Raymond, et al (2010) detected significant effects of the initial conditions, while Raymond, et al. (2009) found a rather small bias. Unfortunately, the initial conditions problem could not be considered in this paper, because a major limitation of this solution is that this procedure has been developed for balanced panels. Since a majority of the firms are observed only in two consecutive periods, this solution is not suitable for us here, as for too many of them the initial condition is identical to the lagged period. Hence, the initial conditions are assumed to be exogenous in the following.

4. Econometric results

$TURNINN_t$ is the dependent variable. On the right-hand side, the lagged dependent variable $TURNINN_{t-1}$ accounts for the persistence of innovation output and the square term $TURNINNsquare_{t-1}$ is included to control for non-linearity of this effect because of the upper boundary that cannot trespassed by definition of the variable. CO_{t-1} is the main predictor (or a vector) of our interest. More specifically, CO_{t-1} refers to the set of lagged dummy variables for location and type of partners for cooperation on innovation $COforEXT_{t-1}$, $COdomEXT_{t-1}$, $COforGP_{t-1}$ and $COdomGP_{t-1}$ and their combinations outlined above. Furthermore, the model accounts for a vector of the other observed predictors x, namely a set of lagged firm-level characteristics $GPnonCO_{t-1}$, $R\&DIN_{t-1}$, $R\&DEX_{t-1}$, MAC_{t-1}, $ROEK_{t-1}$, PAT_{t-1}, $EXPORT_{t-1}$ and $SIZE_{t-1}$, a battery of sector dummies HT, MHT, MLT, LT, KIS and OTH in the current period, where the latter is the base category, and a set of time dummies to control for cross-sectional dependence. It should be noted that the estimates do not suffer from a serious problem of multicollinearity, because these predictors are not excessively correlated to each other.

First, we present estimates of the model on the full sample of firms, which provides the benchmark results. And then we look more closely at differences by size categories of firms by estimating the model separately for small, medium and large firms. To make easier the analysis of national differences, we report results of the same model by country with the Czech Republic in the first, Norway in the second and the United Kingdom in the third column of the regression tables.[10] Marginal effects for the expected value of the (latent) dependent variable (unconditional on the censoring) are reported, i.e. E(y*), where y* = max(a, min(y,b)), a is the lower limit for left censoring and b is the upper limit for right censoring; covariates are fixed at their means.[11] Stata 11 has been used to perform the estimates.

Table 6 gives the first set of results. Since the estimated effects of $TURNINN_{t-1}$ and $TURNINNsquare_{t-1}$ come out positive and highly statistically significant, the results indicate persistence of innovation output and confirm the non-linearity of this relationship. Admittedly, this is in line with expectations given the strategic nature of the decision of firms to innovate and given the fact that other existing papers on this topic based on the CIS data largely support the persistence thesis (Peters 2009, Raymond et al 2009 and Raymond, et al. 2010).

[10] Since the confidential micro data from the Czech Republic and the United Kingdom could have been accessed only in the premises of the respective national statistical offices, and prohibited to take out from the terminal, we could not merge the national datasets together in order to perform the estimates on a combined cross-country sample.

[11] Just as there are three expected values of tobit, i.e. the probability of being uncensored, the expected value of the dependent variable conditional on being uncensored and the unconditional expected value of the dependent variable, there are three corresponding marginal effects that can be possibly reported. But for the sake of space, only the latter marginal effects are reported, because these combine the other two, and therefore their values naturally lie in between of them. Results of the other marginal effects are available from the author upon request.

Table 6: Tobit results for level of TURNINN

	Czech Republic		Norway		United Kingdom	
$TURNINN_{t-1}$	0.368	(0.035)***	0.258	(0.026)***	0.350	(0.026)***
$TURNINNsquare_{t-1}$	-0.303	(0.040)***	-0.182	(0.030)***	-0.260	(0.029)***
$COforEXT_{t-1}$	0.002	(0.009)	0.007	(0.007)	-0.005	(0.009)
$COdomEXT_{t-1}$	0.028	(0.008)***	0.013	(0.006)**	0.021	(0.008)**
$COforGP_{t-1}$	0.015	(0.010)	-0.012	(0.008)	0.005	(0.011)
$COdomGP_{t-1}$	0.019	(0.010)*	0.002	(0.007)	-0.001	(0.009)
$GPnonCO_{t-1}$	0.025	(0.006)***	0.003	(0.004)	0.006	(0.005)
$R\&DIN_{t-1}$	0.632	(0.108)***	0.452	(0.055)***	0.479	(0.090)***
$R\&DEX_{t-1}$	0.304	(0.291)	-0.209	(0.136)	0.139	(0.255)
MAC_{t-1}	0.162	(0.093)*	0.161	(0.084)*	0.148	(0.062)**
$ROEK_{t-1}$	0.395	(0.325)	-0.375	(0.203)*	-0.019	(0.289)
PAT_{t-1}	0.019	(0.009)**	0.024	(0.006)***	0.022	(0.006)***
$EXPORT_{t-1}$	0.004	(0.006)	0.028	(0.004)***	0.027	(0.005)***
$SIZE_{t-1}$	0.018	(0.002)***	0.004	(0.002)**	0.003	(0.002)*
CISw3	0.043	(0.006)***	-0.016	(0.005)***	0.086	(0.018)***
CISw4	0.010	(0.006)*	-0.017	(0.005)***	0.025	(0.006)***
HT	0.091	(0.012)***	0.077	(0.010)***	0.066	(0.016)***
MHT	0.082	(0.009)***	0.072	(0.007)***	0.043	(0.011)***
MLT	0.063	(0.010)***	0.043	(0.007)***	0.036	(0.011)***
LT	0.061	(0.009)***	0.048	(0.006)***	0.040	(0.009)***
KIS	0.066	(0.009)***	0.061	(0.007)***	0.022	(0.008)***
Number of observations	4,750		4,666		5,328	
Number of firms	3,079		2,905		5,013	
σ (e)	0.349	(0.010)***	0.315	(0.006)***	0.469	(0.023)***
Wald χ^2	855.29		1043.47		804.87	
Log-likelihood	-2,204.287		3,798.430		-2,482.114	

Note: Marginal effects reported; for binary variables the marginal effects refer to discrete change from 0 to 1; standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

More interesting, at least for us, is the estimated effect of cooperative behaviour of firms. Somewhat surprisingly, only the $COdomEXT_{t-1}$ dummy for the occurrence of cooperation on innovation with external (not being part of the group) domestic partners comes out highly statistically significant. And this is the case in all three countries. Other modes of cooperation do not seem to make much difference in the innovation output; only perhaps except of within the group in the Czech Republic, which appears weakly significant at 10 and 15% for the domestic and foreign partners, respectively. As far as the magnitude of the marginal effects is concerned, firms that forge cooperation links in the innovation process with external domestic partners are estimated to gain by 1.3 to 2.8 percentage points higher proportion of innovative sales. At the first glance, this might not seem much; however, one needs to compare this to the sample mean reported above, which ranges from 7.9 to 11.1 percent of the total turnover. So the effect actually indicates increase of this proportion by roughly one fourth to one sixth depending on the country, and this is arguably a sizeable boost to the innovative performance of the firm.

Results of the other observed predictors that are not the main concern of this paper are largely according to the expectations. R&DIN $_{t-1}$ has highly significant effect, MAC $_{t-1}$ contributes a bit too, but external sourcing of knowledge – ceteris paribus – represented by R&DEX $_{t-1}$ and ROEK $_{t-1}$ does not make a significant difference. Appropriability conditions of the firm's knowledge based given by the PAT$_{t-1}$ dummy promote the innovation output. SIZE $_{t-1}$ and EXPORT $_{t-1}$ are relevant control variables, except of the Czech Republic, where the latter is not statistically significant, perhaps because most firms in this country have not started to compete on the base of innovation on foreign markets so far, and therefore the supposed learning-by-export effect does not materialize here. Another result in which the Czech Republic stands out is the positive and highly significant effect of GPnonCO $_{t-1}$ which probably reflects the fact that in less advanced countries affiliated firms, in particular foreign affiliates, tend to relatively more depend on straightforward technology transfer from the parent company that does not entail mutual cooperation on developing this technology.

To help us understand what is behind these results of the cooperation variables, particularly with the foreign partners, which is the focal point of this analysis, we repeat the estimate by using the mutually exclusive categories of COboth EXT, COforEXTonly, COdomEXTonly for the external partners and COboth GP, COforGPonly, COdomGPonly for the within group cooperation. Because so many cooperating firms engage simultaneously with foreign and domestic partners (Srholec 2010), which somewhat blurs this distinction, we generate these exclusive categories in order to zoom on those that cooperate only with partners abroad on one hand or only at home on the other hand.

Table 7 shows the results. First, the exclusively external domestic cooperation is the only category that comes out statistically significant at conventional levels across the board, albeit only weakly in Norway. So the capacity to build on domestic linkages is what matters most for the innovation output. Second, cooperation on innovation jointly with domestic and foreign partners, in other words combining local and global linkages, leads to superior innovation performance too, especially in small and open Czech and Norwegian economies, but turns out to be statistically significant only at 15% in the United Kingdom. Third, however, the exclusively external foreign cooperation is clearly the weakest strategy with insignificant effects in Norway and the United Kingdom and a relatively large standard error of the estimated effect in the Czech Republic. Hence, the solely foreign orientation does not seem to pay off. And the cooperative linkages within the group only matter to some extent in the Czech Republic. Overall, the marginal effects suggest that there seems to be much closer connection between cooperation on innovation and the output of the innovation process in the Czech Republic as compared to the other two countries.

Table 7: Tobit results for level of TURNINN

	Czech Republic		Norway		United Kingdom	
$TURNINN_{t-1}$	0.366	(0.035)***	0.259	(0.026)***	0.349	(0.026)***
$TURNINNsquare_{t-1}$	-0.301	(0.040)***	-0.183	(0.030)***	-0.259	(0.029)***
$CObothEXT_{t-1}$	0.029	(0.009)***	0.020	(0.006)***	0.016	(0.011)
$COforEXTonly_{t-1}$	0.030	(0.017)*	0.005	(0.012)	0.001	(0.019)
$COdomEXTonly_{t-1}$	0.035	(0.008)***	0.012	(0.007)*	0.025	(0.009)***
$COboth GP_{t-1}$	0.034	(0.019)*	-0.013	(0.012)	0.013	(0.017)
$COforGPonly_{t-1}$	0.013	(0.011)	-0.009	(0.009)	-0.004	(0.012)
$COdomGPonly_{t-1}$	0.020	(0.012)	0.006	(0.009)	-0.008	(0.010)
$GPnonCO_{t-1}$	0.026	(0.006)***	0.003	(0.004)	0.005	(0.005)
$R\&DIN_{t-1}$	0.623	(0.108)***	0.453	(0.055)***	0.484	(0.090)***
$R\&DEX_{t-1}$	0.314	(0.290)	-0.216	(0.137)	0.155	(0.255)
MAC_{t-1}	0.160	(0.093)*	0.161	(0.084)*	0.147	(0.062)**
$ROEK_{t-1}$	0.398	(0.325)	-0.374	(0.204)*	-0.037	(0.289)
PAT_{t-1}	0.019	(0.009)**	0.024	(0.006)***	0.022	(0.006)***
$EXPORT_{t-1}$	0.005	(0.006)	0.028	(0.004)***	0.027	(0.005)***
$SIZE_{t-1}$	0.018	(0.002)***	0.004	(0.002)**	0.003	(0.002)*
CISw3	0.044	(0.006)***	-0.016	(0.005)***	0.086	(0.018)***
CISw4	0.011	(0.006)*	-0.017	(0.005)***	0.025	(0.006)***
HT	0.090	(0.012)***	0.077	(0.010)***	0.066	(0.016)***
MHT	0.081	(0.009)***	0.072	(0.007)***	0.043	(0.011)***
MLT	0.063	(0.010)***	0.043	(0.007)***	0.036	(0.011)***
LT	0.061	(0.009)***	0.048	(0.006)***	0.040	(0.009)***
KIS	0.066	(0.009)***	0.061	(0.007)***	0.021	(0.008)***
Number of observations	4,750		4,666		5,328	
Number of firms	3,079		2,905		5,013	
σ (e)	0.350	(0.010)***	0.315	(0.006)***	0.468	(0.023)***
Wald χ^2	858.50		1,043.97		806.15	
Log-likelihood	-2,202.391		2,754.570		-2,481.208	

Note: Marginal effects reported; for binary variables the marginal effects refer to discrete change from 0 to 1; standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Furthermore, we test for the possibility that the external and within group cooperative linkages interact with, i.e. complement or substitute, each other in their effects on the innovation output. In other words, for example, we consider the thesis that benefits from foreign external linkages are reinforced by cooperative innovation networks within the group or vice-a-versa. Table 8 gives results of this exercise. Some of the interaction terms appear weakly significant, but there generally does not seem to be a credible support for the connection between within group and external linkages – positive nor negative – which suggests that these networks tend to operate somewhat separately, at least as far as their output in terms of innovative sales is concerned. Arguably, this possibly points to the fact that firms fail to capitalize on the opportunity for cross-fertilization of knowledge available in the internal and external networks.

Table 8: Tobit results for level of TURNINN

	Czech Republic		Norway		United Kingdom	
TURNINN $_{t-1}$	0.366	(0.035)***	0.260	(0.026)***	0.351	(0.026)***
TURNINNsquare $_{t-1}$	-0.301	(0.040)***	-0.184	(0.030)***	-0.261	(0.029)***
CObothEXT_{t-1}	0.032	(0.010)***	0.024	(0.007)***	0.012	(0.014)
* CObothGP_{t-1}	0.035	(0.020)*	-0.021	(0.013)	0.021	(0.022)
* COforGPonly $_{t-1}$	-0.001	(0.015)	-0.017	(0.011)	-0.004	(0.017)
* COdomGPonly $_{t-1}$	0.016	(0.017)	-0.001	(0.012)	-0.001	(0.020)
COforEXTonly$_{t-1}$	0.030	(0.022)	0.015	(0.017)	0.011	(0.026)
* CObothGP_{t-1}	0.000	(0.000)	0.038	(0.061)	-0.012	(0.099)
* COforGPonly $_{t-1}$	0.010	(0.032)	-0.041	(0.025)*	-0.024	(0.029)
* COdomGPonly $_{t-1}$	0.033	(0.080)	0.013	(0.042)	-0.027	(0.041)
COdomEXTonly$_{t-1}$	0.036	(0.009)***	0.007	(0.007)	0.026	(0.010)**
* CObothGP_{t-1}	-0.012	(0.052)	-0.041	(0.039)	-0.022	(0.028)
* COforGPonly $_{t-1}$	0.017	(0.023)	0.006	(0.018)	0.002	(0.028)
* COdomGPonly $_{t-1}$	0.008	(0.019)	0.023	(0.014)*	-0.009	(0.012)
GPnonCO $_{t-1}$	0.024	(0.006)***	0.003	(0.004)	0.005	(0.005)
R&DIN $_{t-1}$	0.616	(0.108)***	0.446	(0.055)***	0.482	(0.090)***
R&DEX $_{t-1}$	0.328	(0.291)	-0.212	(0.137)	0.152	(0.256)
MAC $_{t-1}$	0.157	(0.093)*	0.150	(0.084)*	0.146	(0.062)**
ROEK $_{t-1}$	0.416	(0.324)	-0.378	(0.203)*	-0.036	(0.289)
PAT_{t-1}	0.018	(0.009)**	0.024	(0.006)***	0.021	(0.006)***
EXPORT $_{t-1}$	0.005	(0.006)	0.028	(0.004)***	0.027	(0.005)***
SIZE $_{t-1}$	0.018	(0.002)***	0.004	(0.002)**	0.003	(0.002)*
CISw3	0.044	(0.006)***	-0.016	(0.005)***	0.086	(0.018)***
CISw4	0.011	(0.006)*	-0.017	(0.005)***	0.025	(0.006)***
HT	0.091	(0.012)***	0.077	(0.010)***	0.067	(0.016)***
MHT	0.082	(0.009)***	0.072	(0.007)***	0.043	(0.011)***
MLT	0.063	(0.063)***	0.044	(0.007)***	0.036	(0.011)***
LT	0.061	(0.061)***	0.048	(0.006)***	0.040	(0.009)***
KIS	0.066	(0.066)***	0.061	(0.007)***	0.021	(0.008)***
Number of observations	4,750		4,666		5,328	
Number of firms	3,079		2,905		5,013	
σ (e)	0.350	(0.010)***	0.315	(0.006)***	0.468	(0.023)***
Wald χ^2	856.76		1,051.77		806.72	
Log-likelihood	-2,202.723		2,236.889		-2,480.567	

Note: Marginal effects reported; for binary variables the marginal effects refer to discrete change from 0 to 1; standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

As already noted above, the surveys allow us to further distinguish several types of the external partners for cooperation, which can help us to shed more light on what is behind the results presented above. From this follow the shortcuts SUP for suppliers, CUS for customers, COM for competitors, and SCI for the combined category of commercial labs, universities and public research institutes; note that we combine the latter three categories, because these cooperation partners are relatively rare and because they frequently appear together. Table 9 presents the results. For the sake of space, we do not use the mutually exclusive, i.e. foreign

Table 9: Tobit results for level of TURNINN by the type of CO partner

	Czech Republic		Norway		United Kingdom	
$TURNINN_{t-1}$	0.378	(0.035)***	0.262	(0.026)***	0.350	(0.026)***
$TURNINNsquare_{t-1}$	-0.315	(0.040)***	-0.185	(0.030)***	-0.260	(0.029)***
$COforSUP_{t-1}$	-0.006	(0.010)	0.007	(0.007)	-0.009	(0.010)
$COforCUS_{t-1}$	0.005	(0.010)	-0.002	(0.007)	-0.005	(0.010)
$COforCOM_{t-1}$	-0.017	(0.012)	0.005	(0.008)	0.011	(0.015)
$COforSCI_{t-1}$	0.006	(0.012)	-0.001	(0.008)	-0.004	(0.013)
$COdomSUP_{t-1}$	0.005	(0.009)	-0.002	(0.006)	-0.005	(0.009)
$COdomCUS_{t-1}$	0.005	(0.010)	0.006	(0.007)	0.018	(0.011)*
$COdomCOM_{t-1}$	-0.006	(0.011)	0.004	(0.008)	0.011	(0.011)
$COdomSCI_{t-1}$	0.030	(0.008)***	0.011	(0.006)*	0.011	(0.009)
$COforGP_{t-1}$	0.018	(0.010)*	-0.012	(0.007)	0.007	(0.012)
$CODomGP_{t-1}$	0.019	(0.011)*	0.003	(0.007)	-0.005	(0.009)
$GPnonCO_{t-1}$	0.024	(0.006)***	0.003	(0.004)	0.006	(0.005)
$R\&DIN_{t-1}$	0.629	(0.109)***	0.457	(0.055)***	0.481	(0.091)***
$R\&DEX_{t-1}$	0.305	(0.291)	-0.211	(0.137)	0.134	(0.255)
MAC_{t-1}	0.171	(0.093)*	0.165	(0.084)**	0.156	(0.062)**
$ROEK_{t-1}$	0.417	(0.326)	-0.375	(0.204)*	-0.025	(0.290)
PAT_{t-1}	0.018	(0.009)**	0.024	(0.006)***	0.022	(0.006)***
$EXPORT_{t-1}$	0.004	(0.006)	0.028	(0.004)***	0.027	(0.005)***
$SIZE_{t-1}$	0.018	(0.002)***	0.004	(0.002)**	0.003	(0.002)*
CISw3	0.043	(0.006)***	-0.016	(0.005)***	0.085	(0.018)***
CISw4	0.012	(0.006)*	-0.018	(0.005)***	0.024	(0.006)***
HT	0.092	(0.012)***	0.077	(0.010)***	0.067	(0.016)***
MHT	0.082	(0.010)***	0.072	(0.007)***	0.044	(0.011)***
MLT	0.063	(0.010)***	0.043	(0.007)***	0.036	(0.011)***
LT	0.062	(0.009)***	0.047	(0.006)***	0.040	(0.009)***
KIS	0.067	(0.009)***	0.061	(0.007)***	0.021	(0.008)***
Number of observations	4,750		4,666		5,328	
Number of firms	3,079		2,905		5,013	
σ (e)	0.349	(0.010)***	0.315	(0.006)***	0.466	(0.023)***
Wald χ^2	861.40		1,044.41		806.87	
Log-likelihood	-2,202.752		2,480.994		-2,480.048	

Note: Marginal effects reported; for binary variables the marginal effects refer to discrete change from 0 to 1; standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

only, domestic only or both, categories of cooperation by location, because this would generate fairly long list of the cooperation variables in this estimate. The main outcome is that the positive effect of domestic external cooperation is driven by the education, research and scientific – in other words non-market – institutions in the Czech Republic and to a lesser extent in Norway and the United Kingdom and in addition by the customers and competitors in the United Kingdom. Even though firms cooperate on innovation with the SCI category of partners more rarely than say with their suppliers and customers, which is a well-known fact in the existing literature on this topic (Srholec 2010), these partners appear to be particularly valuable for boosting the innovation output. Admittedly, this finding is encouraging for the literature in the tradition of Etzkowitz and Leydesdorff (2000) that puts emphasis on the role

of industry-university relations in the innovation process of firms. Again, none of the variables of foreign external cooperation did come out even close to be statistically significant at conventional levels.

So far we have not discussed the unobserved effects. At the bottom of the tables is reported the estimated parameter $\sigma(e)$, which indicates the variance attributed to the panel-level (i.e. firm-level) component. If this is close to zero, the unobserved firm-level characteristics do not account for the outcome. Since $\sigma(e)$ has come out highly significantly different from zero in each of the estimates performed so far, the results indicate that indeed the unobserved effects are very important to control for in the dynamic panel data framework, because if not, the variables of interest may pick up the effect of these attributes.

Next, we test robustness of the results by estimating the model separately for three broad size categories of small (0-49 employees), medium (50-249 employees) and large (more than 250 employees) firms. As also already explained above, these surveys are based on a stratified sample in the United Kingdom but on the combination of a stratified sample of small firms (from 10 to 249 employees) and a census of large firms (with at least 250 employees) in the Czech Republic and Norway. As a consequence, in the latter countries large firms have higher likelihood to appear in the sample repeatedly, and in turn for them the panel data is noticeably more "balanced". So besides testing sensitivity of the results to size of the firm, this reveals the extent to which quality of the panel data influences the estimated coefficients, which is a valuable insight in its own right.

Tables 10.1, 10.2 and 10.3 show the results. The main outcome is that $COobothEXT_{t-1}$ and $COdomEXTonly_{t-1}$, i.e. domestic external linkages in combination with the foreign ones or without, matter most for the innovation output of large firms. In other words, the key findings highlighted above hold predominantly for the large firms. To a certain extent this is also the case of medium firms, although the effects are much less significant, except only of the Czech Republic. But small firms seem to operate quite differently in this respect, and there does not seem to be a clear pattern across countries. For the small firms none of the cooperation variables came out statistically significant in the Czech Republic, only $COforEXTonly_{t-1}$ appears relevant in Norway and only $COdomGPonly_{t-1}$ contributes in the United Kingdom. It remains an open question, however, whether this is a real phenomenon or whether this is rather the artefact of more "unbalanced" panels for small firms.

Table 10.1: Tobit results for level of TURNINN by size categories, Czech Republic

	Small		Medium		Large	
$TURNINN_{t-1}$	0.364	(0.067)***	0.380	(0.058)***	0.341	(0.057)***
$TURNINNsquare_{t-1}$	-0.332	(0.078)***	-0.317	(0.072)***	-0.269	(0.062)***
$CObothEXT_{t-1}$	-0.005	(0.025)	0.042	(0.016)***	0.029	(0.013)**
$COforEXTonly_{t-1}$	0.044	(0.039)	0.015	(0.033)	0.030	(0.024)
$COdomEXTonly_{t-1}$	0.006	(0.018)	0.039	(0.014)***	0.037	(0.013)***
$COboth GP_{t-1}$	0.000	(0.000)	-0.007	(0.036)	0.057	(0.026)**
$COforGPonly_{t-1}$	0.019	(0.031)	0.003	(0.022)	0.018	(0.016)
$COdomGPonly_{t-1}$	-0.025	(0.040)	0.033	(0.022)	0.017	(0.018)
$GPnonCO_{t-1}$	0.022	(0.011)**	0.033	(0.009)***	0.024	(0.009)**
$R\&DIN_{t-1}$	0.132	(0.160)	0.390	(0.142)***	1.109	(0.249)***
$R\&DEX_{t-1}$	0.374	(0.723)	0.219	(0.373)	0.573	(0.536)
MAC_{t-1}	0.185	(0.158)	0.312	(0.150)**	-0.034	(0.156)
$ROEK_{t-1}$	0.442	(0.377)	0.127	(0.702)	0.389	(0.581)
PAT_{t-1}	0.050	(0.029)*	0.031	(0.020)	0.020	(0.013)
$EXPORT_{t-1}$	-0.002	(0.010)	0.011	(0.009)	0.000	(0.011)
$SIZE_{t-1}$	0.007	(0.009)	0.029	(0.009)***	0.025	(0.006)***
CISw3	0.009	(0.013)	0.025	(0.012)**	0.067	(0.009)***
CISw4	-0.006	(0.012)	-0.004	(0.011)	0.028	(0.010)***
HT	0.054	(0.020)***	0.078	(0.018)***	0.124	(0.023)***
MHT	0.042	(0.014)***	0.090	(0.015)***	0.108	(0.017)***
MLT	-0.008	(0.025)	0.046	(0.016)***	0.097	(0.017)***
LT	0.030	(0.015)**	0.035	(0.015)**	0.100	(0.016)***
KIS	0.033	(0.012)***	0.065	(0.013)***	0.079	(0.020)***
Number of observations	943		1,530		2,277	
Number of firms	802		1,190		1,220	
σ (e)	0.492	(0.029)***	0.448	(0.017)***	0.286	(0.010)***
Wald χ^2	100.27		270.12		337.98	
Log-likelihood	-394.968		-726.783		-994.467	

Note: Marginal effects reported; for binary variables the marginal effects refer to discrete change from 0 to 1; standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table 10.2: Tobit results for level of TURNINN by size categories, Norway

	Small		Medium		Large	
$TURNINN_{t-1}$	0.263	(0.044)***	0.249	(0.039)***	0.264	(0.072)***
$TURNINNsquare_{t-1}$	-0.177	(0.050)***	-0.185	(0.042)***	-0.196	(0.083)**
$CObothEXT_{t-1}$	0.010	(0.012)	0.014	(0.008)*	0.053	(0.017)***
$COforEXTonly_{t-1}$	0.051	(0.025)**	-0.013	(0.016)	0.016	(0.029)
$COdomEXTonly_{t-1}$	0.017	(0.012)	-0.005	(0.009)	0.042	(0.016)***
$COboth GP_{t-1}$	-0.048	(0.039)	0.016	(0.017)	-0.032	(0.025)
$COforGPonly_{t-1}$	-0.020	(0.019)	0.006	(0.011)	-0.028	(0.022)
$COdomGPonly_{t-1}$	0.010	(0.018)	-0.006	(0.011)	0.029	(0.022)
$GPnonCO_{t-1}$	0.005	(0.007)	-0.002	(0.006)	0.027	(0.017)
$R\&DIN_{t-1}$	0.426	(0.078)***	0.482	(0.092)***	0.066	(0.216)
$R\&DEX_{t-1}$	-0.158	(0.194)	-0.427	(0.237)*	0.421	(0.393)
MAC_{t-1}	0.177	(0.139)	0.175	(0.116)	0.090	(0.233)
$ROEK_{t-1}$	-0.639	(0.319)**	-0.118	(0.261)	-1.585	(1.072)
PAT_{t-1}	0.024	(0.011)**	0.027	(0.007)***	0.034	(0.013)**
$EXPORT_{t-1}$	0.034	(0.007)***	0.028	(0.006)***	0.013	(0.012)
$SIZE_{t-1}$	0.007	(0.007)	0.001	(0.006)	-0.011	(0.008)
CISw3	-0.026	(0.009)***	-0.011	(0.006)*	-0.017	(0.012)
CISw4	-0.018	(0.008)**	-0.020	(0.006)***	-0.011	(0.013)
HT	0.094	(0.016)***	0.046	(0.015)***	0.138	(0.025)***
MHT	0.081	(0.013)***	0.058	(0.010)***	0.101	(0.019)***
MLT	0.053	(0.013)***	0.025	(0.009)***	0.083	(0.016)***
LT	0.047	(0.013)***	0.035	(0.008)***	0.085	(0.015)***
KIS	0.076	(0.013)***	0.033	(0.010)***	0.103	(0.016)***
Number of observations	1,765		2,213		688	
Number of firms	1,402		1,306		399	
σ (e)	0.370	(0.013)***	0.290	(0.011)***	0.258	(0.011)***
Wald χ^2	409.09		431.45		195.05	
Log-likelihood	2,250.528		-781.122		475.361	

Note: Marginal effects reported; for binary variables the marginal effects refer to discrete change from 0 to 1; standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

Table 10.2: Tobit results for level of TURNINN by size categories, United Kingdom

	Small		Medium		Large	
$TURNINN_{t-1}$	0.300	(0.036)***	0.382	(0.050)***	0.435	(0.055)***
$TURNINNsquare_{t-1}$	-0.225	(0.040)***	-0.266	(0.056)***	-0.340	(0.063)***
$CObothEXT_{t-1}$	0.018	(0.018)	0.010	(0.020)	0.015	(0.020)
$COforEXTonly_{t-1}$	0.018	(0.036)	-0.005	(0.034)	-0.014	(0.029)
$COdomEXTonly_{t-1}$	0.018	(0.013)	0.026	(0.017)	0.035	(0.021)*
$COboth GP_{t-1}$	-0.003	(0.034)	0.013	(0.036)	0.024	(0.029)
$COforGPonly_{t-1}$	-0.008	(0.022)	0.017	(0.029)	-0.009	(0.021)
$COdomGPonly_{t-1}$	-0.022	(0.011)**	0.020	(0.023)	-0.011	(0.020)
$GPnonCO_{t-1}$	0.004	(0.008)	0.000	(0.009)	0.015	(0.011)
$R\&DIN_{t-1}$	0.398	(0.124)***	0.610	(0.167)***	0.511	(0.223)**
$R\&DEX_{t-1}$	0.071	(0.275)	0.322	(0.680)	1.131	(1.195)
MAC_{t-1}	0.105	(0.078)	0.142	(0.129)	0.251	(0.153)
$ROEK_{t-1}$	0.251	(0.345)	-0.572	(0.694)	-0.496	(0.873)
PAT_{t-1}	0.030	(0.010)***	0.006	(0.011)	0.026	(0.011)**
$EXPORT_{t-1}$	0.020	(0.007)***	0.043	(0.010)***	0.018	(0.011)*
$SIZE_{t-1}$	0.006	(0.007)	-0.013	(0.010)	0.002	(0.006)
CISw3	0.068	(0.056)	0.098	(0.033)***	0.070	(0.026)***
CISw4	0.028	(0.007)***	0.027	(0.011)**	0.016	(0.014)
HT	0.052	(0.023)**	0.046	(0.029)	0.128	(0.038)***
MHT	0.022	(0.014)	0.044	(0.023)*	0.086	(0.027)***
MLT	0.039	(0.014)***	0.017	(0.019)	0.051	(0.029)*
LT	0.034	(0.012)***	0.042	(0.020)**	0.051	(0.021)**
KIS	0.026	(0.011)**	0.016	(0.016)	0.027	(0.016)
Number of observations	2,586		1,338		1,404	
Number of firms	2,565		1,273		1,222	
σ (e)	0.436	(0.137)***	0.403	(0.046)***	0.429	(0.016)***
Wald χ^2	286.40		255.39		290.93	
Log-likelihood	-1,155.175		-617.429		-676.224	

Note: Marginal effects reported; for binary variables the marginal effects refer to discrete change from 0 to 1; standard errors in brackets; ***, **, and * indicate significance at the 1, 5, and 10 percent level.

5. Conclusions

Overall, the big picture that comes out from these results is that domestic linkages rule. In other words, the capacity to build on domestic linkages is what pays off most for the innovation output. Admittedly, this confirms the notion that international business does not undermine the role of local innovation systems (Narula 2003). Quite the contrary in fact tends to be the outcome of globalization of production and technology (Maskell and Malmberg 1999, Rugman and D'Cruz 2003). Even if firms invest and cooperate abroad to tap into foreign sources of tacit knowledge (Chesnais 1992, Cantwell 1995), their strategic capabilities remain embedded in local innovation systems. Pavitt and Patel (1991) and Patel and Vega (1999) conclusions on "non-globalization" of core technological competencies appear as relevant as ever.

Nevertheless, cooperation on innovation jointly with domestic and foreign partners, in other words combining local and global linkages, leads to superior innovation performance too, especially in small and open Czech and Norwegian economies. Here the results concord with the arguments aired by Bathelt et al. (2004) on the key role of interactions between learning processes taking place among actors embedded in the "local buzz" and knowledge obtained by building "global pipelines" to sources outside of the local milieu, because exactly the co-existence of high levels of buzz and many pipelines provides firms with a string of particular advantages not available to outsiders. Hence, foreign external linkages are valuable but only in combination with the domestic ones.

Furthermore, the positive effect of domestic cooperation appears to be driven by linkages to education, research and scientific institutions. Even though firms cooperate on innovation with these types of partners, especially universities and government labs, less frequently than say with their suppliers and customers, as well-known in the existing literature on this topic (Srholec 2010), these partners come out to be particularly valuable for boosting the innovation output. Arguably, this finding is encouraging for the literature in the tradition of Etzkowitz and Leydesdorff (2000) that puts emphasis on the role of industry-university relations in the innovation process of firms.

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